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WATER QUALITY IN FAUNTLEROY CREEK AND COVE DURING THE SUMMER OF 1988

by
Will Kendra

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Surface Water Investigations Section
Olympia, Washington 98504

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ABSTRACT

A water quality survey of Fauntleroy Creek and Cove was performed during June and August 1988. Current studies showed offshore circulation was tidally-driven, while nearshore circulation was both tidally- and wind-driven. A decaying algal mat located 500 feet south of the ferry dock was identified as the source of local sulfide odors. Nearshore currents were restricted in the vicinity of the algal bed. Algal productivity was high, with evidence that nitrogen was limiting plant growth. Fauntleroy Creek was a major source of nitrogen loading to the inner cove, with unknown effect on nearshore eutrophication. Bacterial studies revealed fecal contamination of Fauntleroy Creek and marine waters adjacent to the creek. Sources of nitrogen and fecal coliform loading to the creek are believed to be nonpoint in origin.

INTRODUCTION

Fauntleroy Creek and Cove are located four miles south of Alki Point in West Seattle. Fauntleroy Creek arises from springs in a boggy woodland. Two major and several minor tributaries constitute the headwaters. The stream corridor is largely undeveloped in its upper reaches, with residential encroachment increasing toward the mouth. The creek drops 300 feet in elevation over 0.8 mile before entering Puget Sound at Fauntleroy Cove.

Fauntleroy Cove is bounded by Williams and Brace Points (Figure 1). The Vashon Ferry dock and terminal are located midway between the points. The shoreline north of the dock has limited residential development, with Lincoln Park occupying most of the waterfront. To the south, residences border the cove entirely. Fauntleroy Creek drains into the cove about 50 feet south of the ferry dock.

Fauntleroy Cove has experienced recurrent odor problems in summer months, particularly August. Some local residents contend the foul odors originate from improper sewage disposal practices by ferries, namely direct discharge of raw sewage to the cove and/or leakage during sewage transfer to a nearby METRO pump station. In recent years, a number of agencies and organizations have investigated these and related allegations, including:

- City of Seattle
- Envirotest (consulting firm)
- METRO (Municipality of Metropolitan Seattle)
- Puget Sound Air Pollution Control Authority
- Seattle/King County Health Department
- University of Washington
- U.S. Environmental Protection Agency (EPA)
- Washington State Departments of Ecology, Natural Resources, and Transportation.

Their collective activities to date are briefly summarized below:

- Inspection of ferry waste storage and disposal practices; dye testing of transfer lines; modification of holding and off-loading procedures, including pretreatment of waste.

- Upgrade of METRO's Barton Street pump station to increase storage and control odors (carbon filtration).

- Hydrogen sulfide monitoring in Barton Street pump station, nearby manholes, and adjacent residential neighborhood.

- Inspection and dye testing of sanitary sewer lines in watershed and along beach; effort to locate septic tank failures.

- Fecal coliform sampling in creek, cove, sediments, interstitial water, and storm sewers; nutrient/algal study in cove; underwater video survey of cove.

Investigators found no evidence of ferries discharging sewage to the environment. Elevated fecal coliform levels in the cove appeared to be linked to bacterial contamination in Fauntleroy Creek. Thom (1985) traced the odor problem to the accumulation and decay of macroalgae in an area of restricted circulation 500 feet south of the ferry dock. Intensive sulfide monitoring during the summer of 1988 confirmed that algal mats in this area were the source of foul odors in the shoreline vicinity (B. Newman, Ecology, personal communication). Concurrent odor events at Lowman Beach (north of Williams Point) were also caused by decaying algae.

In 1988, Ecology coordinated a multi-agency attempt to identify and fill remaining data gaps concerning the recurrent odor problem at Fauntleroy. One identified task was the collection of additional water quality data in Fauntleroy Creek and Cove. The Surface Water Investigations Section of Ecology performed this task in June and August of 1988. Study objectives were:

1. To characterize water quality in the creek and cove before and during the foul odor period; and

2. To document cove circulation patterns during ebb and flood tides, especially near the creek mouth and ferry dock.

Survey findings are reported herein.

METHODS

Sampling

Monitoring activities were scheduled to coincide with spring tide conditions (Figure 2). Offshore current studies were conducted on June 14; nearshore currents were measured each sampling day. Intensive water quality surveys were conducted on June 15 and August 29. Several water quality samples were also collected on August 9 during a particularly foul odor event.

Offshore currents were assessed by tracking drift drogues which were released near the seaward end of the ferry dock. Drogues were set at a depth of three feet below the surface.

Drogue positions were periodically fixed using a hand-bearing compass. Nearshore currents were studied by visually tracking the movement of fluorescent dye which was added to shallow marine surface waters and the creek at its mouth.

Water quality sampling sites are shown in Figure 1. Stream samples and nearshore (1 - 2 feet deep) marine samples were collected by hand from just beneath the surface. Offshore samples were collected near the surface (by hand) and at a depth of 30 feet (by Kemmerer bottle). Offshore sites were located over total water depths of about 40 feet (end of ferry dock) and 70 feet (between Williams and Brace Points).

Field measurements included streamflow by Swoffer current meter and top-setting rod; temperature, pH, and conductivity by Beckman meters; salinity by Kahlsico meter (August 29); and dissolved oxygen and total sulfides (August 9 only) by iodometric techniques.

Laboratory measurements were salinity (June 15), total suspended solids, nutrients (ammonia, nitrate-plus-nitrite, and total phosphorus), fecal coliform, and fecal streptococcus (August 29 only). Samples for lab analysis were iced immediately and shipped within 24 hours to the EPA/Ecology Laboratory in Manchester, Washington. Sample containers, processing, and analysis conformed to EPA (1983), APHA *et al.* (1985), and Huntamer (1986).

Field assistance was provided by Barbara Carey, Randy Coots, and Bob Newman of Ecology. Weather was sunny on June 14 and 15, somewhat overcast on August 9, and light rainfall on August 29. Wind direction was estimated during all sampling events to aid in the interpretation of nearshore current patterns.

<u>Quality Assurance</u>

Replicate samples were collected to assess sampling and analytical variability. Similarity of each replicate pair was measured by calculating the relative percent difference (RPD), defined as the difference between two replicates divided by their mean. Results were expressed using box plots (Figure 3).

Box plots graphically depict the distribution of a series of data points (McGill *et al.* 1978). The line within the box represents the median (the middle value of a series of values arranged in order of magnitude). The box itself represents the interquartile range (the values at the 25th and 75th percentiles of the ranked data set). Vertical lines project above and below the box to the maximum and minimum values, respectively.

Figure 3 shows the distribution of RPDs for replicated variables. Four parameters showed considerable variation: fecal coliform, ammonia, total sulfides, and total suspended solids. The high RPDs for fecal coliform and ammonia are of little significance since they occurred at lower ranges of detection (e.g., replicate coliform values of 1 and 2 yielded an RPD of 67 percent). Total sulfides were replicated only once, hence the box plot for this parameter represents a single RPD. High variability in total sulfides was expected given that sampling occurred as the flood tide inundated the decaying algal mat. Variation in suspended solids likely reflects disturbance of bottom sediments by wave and tidal action.

RESULTS AND DISCUSSION

Cove Circulation

Offshore circulation patterns in Fauntleroy Cove are depicted in Figure 4. During ebb tide, currents transported the drogues southward at moderate speed. On the flood tide, variable currents were observed. A strong northward current was measured after one drogue release, but a weak offshore current was evident following another release. Three conclusions may be drawn from these results:

1. Offshore currents in the cove appeared to be driven by tidally-induced gyres. On ebb tide, waters draining northward out of Puget Sound were deflected to the south by Williams Point. During flood tide, southward-moving waters were deflected northward by Brace Point.

2. The weak offshore-moving current observed during flood tide may be caused by restricted circulation under the ferry dock. Sediments have accumulated around dock pilings to the extent that waters moving parallel to shore may be deflected westward, producing a weak offshore current.

3. Drogue releases demonstrated offshore current movement to the north, west, or south. Surface waters near the end of the dock were not transported directly shoreward (east). Thus, any discharge by a docked ferry would likely exit the cove without contacting the nearshore algal bed in question.

Dye releases during ebb and flood tides on June 14 showed nearshore currents moving southward. A preliminary hypothesis that nearshore circulation was largely wind-driven was tested through dye studies on subsequent sampling trips. Results of these studies (presented with water quality findings below) indicate that nearshore currents were generated by both wind and tidal forces, and modified by local bathymetry.

Cove Water Quality

Water quality data for Fauntleroy Creek and Cove are provided in Table 1. Data from ebb and flood sampling on June 15 and August 29 are pictorially summarized in Figure 5. A brief discussion of each water quality parameter follows:

- Temperature (Figure 5a). Warming of the inner cove was evident in June, especially during the afternoon flood tide. Restricted circulation of nearshore waters resulted in temperatures as high as 23^{o}C (73^{o}F). Uniformly low temperatures on August 29 were likely caused by cooling associated with a storm event (low pressure/rainfall).

- pH (Figure 5b). Highest pH values were observed south of the dock, near the algal bed, on both the ebb and flood tides of June 15 (Table 1). Elevated nearshore pH was attributed to algal production (photosynthesis).

- Dissolved oxygen (Figure 5c). Like pH, dissolved oxygen also peaked in nearshore waters. Again, levels were highest near the algal bed (oxygen is a byproduct of plant photosynthesis). Reduced oxygen concentrations on August 29 probably indicate diminished algal production related to seasonal influences. Plant productivity in Puget Sound generally peaks in spring and early summer; algal respiration and decomposition deplete oxygen levels in late summer and fall (Dexter *et al.* 1981, 1985).

- Salinity (Figure 5d). Two trends are apparent: 1) lower salinity south of the dock caused by inflow of Fauntleroy Creek; and 2) higher salinity in August caused by decreased freshwater discharge to the Sound and coastal upwelling (Dexter *et al.* 1981, 1985).

- Total suspended solids (Figure 5e). Solids results were highly variable, but wind (and thus wave action) appeared to play a role. Solids were lowest during ebb tide sampling on August 29, when relatively calm winds prevailed.

- Total inorganic nitrogen (Figure 5f). Nitrogen levels in the creek were considerably higher than in the cove (0.8 vs. 0.2 mg/L). Nitrogen depletion in June was probably linked to increased algal production, as nitrogen is one of several elements required for plant growth. Increased nitrogen in August may be attributed to nutrient release associated with algal decay and/or upwelling of nutrient-rich coastal waters (Dexter *et al.* 1981, 1985).

- Total phosphorus (Figure 5g). The spatial and temporal distribution of phosphorus strongly resembled that of nitrogen. Phosphorus, like nitrogen, is also essential for plant growth. Seasonal changes in phosphorus are probably driven by the same forces which influence nitrogen, namely biological productivity and coastal upwelling.

- Fecal coliform (Figure 5h). Fecal coliform were elevated in the creek and in marine waters south of the ferry dock. Current patterns implicate the creek as a likely source of nearshore bacterial contamination.

Nutrient limitation of algal growth in nearshore waters was evidenced in June. Nitrogen is typically the limiting nutrient in marine ecosystems. Nitrogen limitation may occur when total inorganic nitrogen levels drop to 0.04-0.10 mg/L and nitrogen-phosphorus (N:P) ratios fall below 5:1 by weight (Ryther and Dunstan 1971; URS 1986; SAIC 1987). These conditions existed in the vicinity of the algal bed on June 15 (Table 1). Earlier investigators similarly documented nearshore nitrogen limitation in Fauntleroy Cove (Thom 1985; Thom *et al.* 1988).

Limited nearshore sampling was performed on August 9 during an offensive odor event. The algal mat south of the ferry dock was determined to be the source of the sulfide (rotten egg) odor. There was no wind during sampling, and nearshore currents were directed southward.

Findings are shown in Figure 6. Waters near the algal bed were clearly of different quality than those nearby. The algal mat was black in color beneath the immediate surface and total sulfides were detected in water samples. In addition, the southernmost site had depressed pH and dissolved oxygen. All of these features characterize anaerobic decomposition and further indicate localized nearshore eutrophication.

Fecal coliform sampling on August 9 confirmed that Fauntleroy Creek was the primary source of fecal contamination in the nearshore cove environment. Bacterial levels were highest in the creek and at sites adjacent to the creek mouth. Sampling by METRO (1988) produced similar results during the previous year. Low coliform levels at the two algal mat sites indicated that the decaying seaweed bed was not contaminated with raw sewage.

Fauntleroy Cove is rated a Class AA (extraordinary) water body in state water quality standards (WAC 173-201). Fecal coliform criteria intended to protect beneficial uses (shellfishing, swimming, etc.) in Class AA marine waters are as follows: "Fecal coliform organisms shall not exceed a geometric mean value of 14 organisms/100 mL, with not more than 10 percent of samples exceeding 43 organisms/100 mL." The mean of all nearshore samples collected during this study was 26 organisms/100 mL, with 37 percent of samples exceeding 43 organisms/100 mL (Table 1).

Creek Water Quality

Results of sampling along the length of Fauntleroy Creek are presented in Table 1. Temperature, pH, conductivity, dissolved oxygen, and total suspended solids were relatively uniform from headwaters to mouth. Flow was 0.1 cfs below the confluence of headwater tributaries and 0.3-0.4 cfs at the three downstream sites. Other small tributaries and ground water inputs probably account for the flow increase between mile 0.6 and 0.4.

Instream nutrient and bacteria concentrations are plotted in Figure 7. Phophorus levels were unchanged from headwaters to mouth, but inorganic nitrogen showed a sharp increase between mile 0.6 and 0.4. Fecal coliform densities were high on both sampling dates, with evidence of a downstream increase on August 29.

The elevated nitrogen levels are of particular concern because of nearshore eutrophication in Fauntleroy Cove. The creek contributes about 1-2 pounds of inorganic nitrogen to the cove daily. Mass balance calculations show that the inflow between mile 0.6 and 0.4 had total inorganic nitrogen concentrations of 1.0-1.1 mg/L. The source of nitrogen is unknown, but fertilizer use in the watershed is suspected.

Fauntleroy Creek is also rated a Class AA water in state water quality standards. Bacterial criteria for Class AA freshwaters are: "fecal coliform organisms shall not exceed a geometric mean value of 50 organisms/100 mL, with not more than 10 percent of samples exceeding 100 organisms/100 mL." Stream samples during the present survey had a mean of 1,300 organisms/100 mL, with all 15 samples exceeding 100 organisms/100 mL.

METRO (1988) has previously studied fecal contamination in Fauntleroy Creek. They found higher levels in summer compared to winter, with no apparent trend in location. Instream bacterial levels were similar to other small urban streams monitored in King County (T. Sample, METRO, personal communication). A sanitary sewer line which parallels the creek has been dye tested for leakage, with negative results. METRO believes the fecal contamination is related to animal keeping practices in the watershed.

Two fecal streptococcus samples were collected on August 29 to determine if fecal wastes in the creek and cove were of human or animal origin (Table 1). Geldreich (1976) suggested that ratios of fecal coliform to fecal streptococcus (FC:FS) above four are indicative of human fecal matter, while ratios under 0.6 characterize other warm-blooded animals. Ratios between 0.7 and 3.0 are regarded as inconclusive due to aging of fecal wastes (i.e., differential die-off rates of FC and FS). To minimize effects of aging, the two FC/FS samples collected on August 29 were transported by boat to the Manchester laboratory for immediate analysis.

FC:FS ratios at the creek mouth and near the algal bed were 0.4 and 0.3, respectively. These results indicate that fecal contamination of the creek and cove likely originated from animal, rather than human, sources. Geldreich further noted that domestic animals had FC:FS ratios of 0.1 to 0.6, whereas wildlife ratios were less than 0.1. Consequently, the ratios observed here support METRO's contention that fecal pollution in the creek may be linked to animal keeping practices in the community.

CONCLUSIONS AND RECOMMENDATIONS

Considerable effort has been expended by various parties investigating complaints of foul odors and fecal contamination in Fauntleroy Cove. The odors have been traced to a decaying algal bed 500 feet south of the ferry dock. No evidence of raw sewage discharge by ferries has ever been documented. Drogue studies revealed than any material discharged by ferries would likely be transported seaward, rather than shoreward.

The algal bed in question is located in an area of restricted circulation. During periods of high productivity, nitrogen may limit algal growth in nearshore waters. This finding is noteworthy because the adjacent inflow of Fauntleroy Creek delivers a nitrogen load of 1 - 2 pounds to the marine environment each day. Instream nitrogen likely derives from fertilizer use in the watershed. Upon discharge to the cove, the nitrogen again acts as a fertilizer, this time contributing to nearshore eutrophication.

Fecal coliform bacteria were elevated in Fauntleroy Creek and in shallow marine waters near the creek mouth. State water quality standards for fecal coliform were frequently violated. By contrast, fecal coliform levels near the algal bed were relatively low. The source of fecal pollution in the creek appears to be domestic animal waste.

There is little need for additional water quality work at Fauntleroy. Instream nitrogen sampling between mile 0.6 and 0.4 may be instructive, but nonpoint sources are suspected. Fecal contamination in the watershed has received extensive study and further investigation would likely be fruitless. The present work and historical studies have demonstrated that Fauntleroy Creek is a major source of nutrient and fecal loading to nearshore cove waters in summer months.

Several remedial actions have been proposed to alleviate or eliminate the recurrent odor events (Thom *et al.* 1985):

- Diversion of the lower creek into a nearby storm sewer for ultimate discharge to deeper water. This action would reduce nitrogen loading to the inner cove, with unknown effect on nearshore algal productivity. A secondary result of diversion would be export of fecal coliform contamination to a more well-mixed environment.

- Removal of stranded algal mats during critical odor periods. This activity was performed in 1985 with moderate success in reducing odors; additional trials are warranted.

- Increasing circulation in the inner cove to prevent algal accumulation. To accomplish this, current movement and sediment deposition in the cove must be studied further. Increased understanding of these processes may lead to development of corrective measures (e.g., ferry dock modifications to improve circulation).

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Table 1. Water quality in Fauntleroy Creek and Cove during June and August 1988.

Site	River Mile	Date	Time*	Sample Depth (ft)	Tide Height (ft)**	Flow (cfs)	Temperature (°C)	pH (units)	Conductivity (umhos/cm)	Salinity (ppt)	Diss. Oxygen (mg/L)	Diss. Oxygen (% sat)	Total Sulfide (mg/L)	TSS (mg/L)	NH_3N (mg/L)	NO_3-N + NO_2-N (mg/L)	Total P (mg/L)	Bacteria: Fecal Coliform (#/100 mL)	Bacteria: Fecal Strep. (#/100 mL)
Fauntleroy Creek																			
Mouth, 50 ft S of ferry dock	0.0	6/15	1030	0	--	--	14.3	8.4	290	--	11.10	108	--	23	0.03	0.76	0.02	930	--
			1235	0	--	0.3	14.7	8.4	300	--	10.90	107	--	25	0.02	0.76	0.10	1400	--
			1235R	0	--	0.3	14.6	8.4	300	--	10.90	107	--	22	0.05	0.53	0.10	1300	--
			1620	0	--	--	16.4	8.4	290	--	10.65	108	--	19	0.03	0.74	0.06	1400	--
		8/9	1235	0	--		14.5	8.5	--	--	--	--	--	--	--	--	--	830	--
		8/29	1100	0	--	--	14.1	8.2	310	--	10.40	101	--	44	0.02	0.86	0.13	2700	6300
			1315	0	--	0.4	14.0	8.6	290	--	10.50	101	--	34	0.01	0.82	0.10	1700	--
			1315R	0	--	0.3	14.0	8.4	280	--	10.55	102	--	32	0.02	0.83	0.10	1700	--
			1550	0	--	--	14.4	8.4	280	--	10.70	104		20	0.01	0.78	0.09	2000	--
45th Ave SW	0.2	6/15	1315	0	--	0.4	14.3	8.2	290	--	10.75	105	--	21	0.02	0.79	0.10	1400	--
		8/29	1705	0	--	0.3	14.2	8.2	290	--	10.25	100	--	19	0.01	0.81	0.09	1300	--
Barton St SW	0.4	6/15	1345	0	--	0.3	14.3	8.3	300	--	10.75	105	--	21	0.01	0.79	0.10	1200	--
		8/29	1745	0	--	0.3	14.0	8.6	290	--	10.45	101	--	22	<0.01	0.81	0.10	800	--
Below confluence of headwaters	0.6	6/15	1415	0	--	0.1	14.6	8.3	320	--	10.10	99	--	21	0.02	0.38	0.09	1500	--
		8/29	1820	0	--	0.1	14.0	8.6	300	--	9.95	97	--	17	0.01	0.27	0.08	590	--
Fauntleroy Cove, Nearshore																			
Williams Point	--	6/15	0955	0	0E	--	12.6	8.1	--	28	11.00	122	--	31	0.05	0.16	0.02	<4	--
			1520	0	2F	--	16.1	8.4	--	28	16.70	198	--	16	0.03	0.10	0.06	<4	--
		8/29	0920	0	7E	--	12.9	7.9	--	30	7.65	86	--	4	0.02	0.20	0.07	13	--
			1615	0	7F		13.3	8.0	--	30	8.60	98	--	14	0.02	0.23	0.07	4	
500 ft N of ferry dock	--	6/15	1010	0	0E	--	14.2	8.2	--	28	11.35	130	--	21	0.02	0.16	0.02	6	--
			1640	0	6F	--	23.0	8.4	--	28	13.00	176	--	18	0.02	0.08	<0.01	340	--
		8/9	1215	0	1F	--	14.2	8.2	--	--	11.00	--	<1.0	--	--	--	--	220	
		8/29	0945	0	5E	--	12.9	8.0	--	30	7.70	87	--	10	0.02	0.20	0.06	4	--
			1600	0	6F	--	13.4	8.0	--	30	9.00	103	--	28	0.01	0.22	0.07	3	--
25 ft S of ferry dock	--	6/15	1040	0	-1E	--	13.5	8.3	--	26	12.35	138	--	23	0.05	0.23	0.16	360	--
			1625	0	6F	--	18.0	8.5	--	28	14.25	176	--	22	0.03	0.12	0.02	210	--
		8/9	1225	0	2F	--	13.6	8.2	--	--	--	--	--	--		--	--	730	--
		8/29	1000	0	5E	--	13.1	8.0	--	29	7.95	90	--	5	0.01	0.20	0.07	66	--
			1545	0	5F	--	13.6	8.1	--	29	9.30	106	--	12	0.01	0.21	0.06	7	--
50 ft S of ferry dock, off creek mouth	--	6/15	1050	0	-1E	--	15.0	9.0	--	28	23.50	273	--	23	0.03	0.03	0.02	34	--
			1610	0	4F	--	18.0	8.5	--	26	13.30	162	--	13	0.03	0.24	0.13	1900	--
		8/9	1230	0	2F	--	14.0	8.2		--	--	--	--	--	--	--	--	590	--
		8/29	1040	0	3E	--	13.4	7.9	--	--	8.20	--	--	9	0.01	0.20	0.07	150	--
			1540	0	5F	--	13.9	8.2	--	30	9.50	110	--	29	0.01	0.21	0.07	31	--

Table 1. Continued

Site	River Mile	Date	Time *	Sample Depth (ft)	Tide Height (ft)**	Flow (cfs)	Temperature (°C)	pH (units)	Conductivity (umhos/cm)	Salinity (ppt)	Diss. Oxygen (mg/L)	Diss. Oxygen (% sat)	Total Sulfide (mg/L)	TSS (mg/L)	Nutrients: NH_3-N (mg/L)	Nutrients: NO_3-N + NO_2-N (mg/L)	Nutrients: Total P (mg/L)	Bacteria: Fecal Coliform (#/100 mL)	Bacteria: Fecal Strep. (#/100 mL)
500 ft S of ferry dock	--	6/15	1100	0	-2E	--	14.5	8.7	--	28	19.55	225	--	24	0.02	0.05	0.02	9	--
			1600	0	4F	--	22.4	8.9	--	28	17.00	228	--	19	0.02	0.05	0.02	6	--
			1600R	0	4F	--	21.8	9.0	--	28	17.65	234	--	8	0.04	0.05	0.02	3	--
		8/9	1250	0	3F	--	17.9	8.2	--	--	10.75	--	1.6	--	--	--	--	27	--
			1250R	0	3F	--	--	--	--	--	10.85	--	3.5	--	--		--	--	--
		8/29	1050	0	3E	--	13.3	7.8	--	30	8.20	94	--	8	0.04	0.21	0.08	150	510
			1520	0	4F	--	14.2	8.2	--	30	10.10	117	--	7	0.01	0.21	0.07	33	--
			1520R	0	4F		13.9	8.3	--	30	10.05	116	--	11	0.01	0.22	0.07	8	--
750 ft S of ferry dock	--	8/9	1300	0	3F	--	20.3	6.8	--	--	2.55	--	2.5		--	--	--	88	--
Brace Point		6/15	1110	0	-2E	--	12.5	8.3	--	27	12.45	137	--	24	0.02	0.10	0.02	<4	--
			1540	0	3F	--	14.8	8.5	--	28	15.05	174	--	19	0.01	0.07	0.01	<4	--
		8/29	1505	0	3F	--	13.8	8.3	--	30	11.45	132	--	8	0.01	0.21	0.07	6	--
Fauntleroy Cove, Offshore																			
Seaward end of ferry dock		6/15	1130	0	-2E	--	12.3	8.3	--	28	13.55	149	--	14	0.01	0.10	0.02	<4	--
			1130R	0	-2E	--	12.5	8.3	--	28	13.90	154	--	21	0.09	0.12	0.02	<4	--
			1135	30	-2E	--	13.7	8.3	--	28	12.40	141	--	22	0.02	0.12	0.02	<4	--
			1500	0	1F	--	11.7	8.3	--	28	12.20	133	--	14	0.05	0.16	0.02	<4	--
			1500	30	1F	--	12.9	8.2	--	29	10.50	118	--	8	0.04	0.19	0.01	<4	--
		8/29	1130	0	2E	--	13.0	8.0	--	30	7.75	88	--	7	0.01	0.24	0.07	2	--
			1130R	0	2E		13.0	8.0	--	30	7.70	87	--	6	0.01	0.24	0.07	1	--
			1140	30	2E	--	12.8	7.9	--	30	7.40	84	--	6	0.01	0.25	0.07	<1	--
			1445	0	3F	--	12.9	8.2	--	30	7.80	88	--	10	0.01	0.23	0.06	<1	--
			1450	30	3F		13.2	8.2	--	30	7.70	88	--	19	0.02	0.24	0.07	1	
1,000 ft W of ferry dock, on line between Williams and Brace Points	--	6/15	1150	0	-2E	--	14.5	8.5	--	28	14.80	170	--	25	0.02	<0.01	0.01	<4	--
			1150	30	-2E	--	12.9	8.3	--	28	11.70	131	--	18	0.01	0.14	<0.01	6	--
			1510	0	2F	--	12.2	8.2	--	29	12.00	133	--	22	0.04	0.15	0.01	<4	--
			1510	30	2F	--	11.9	8.2	--	29	10.60	117	--	22	0.08	0.18	0.06	<4	--
		8/29	1115	0	2E	--	12.7	7.8	--	30	7.60	86	--	5	0.01	0.24	0.07	<1	--
			1120	30	2E	--	12.7	7.9		30	7.35	83	--	1	0.01	0.25	0.07	1	--
			1400	0	2F	--	13.0	8.3	--	30	8.30	94	--	25	0.01	0.23	0.06	<1	--
			1430	30	2F	--	13.0	8.2	--	30	7.75	88		23	0.01	0.24	0.07	<1	--

* R = Replicate.
** E - Ebb (falling) tide; F = Flood (rising) tide.

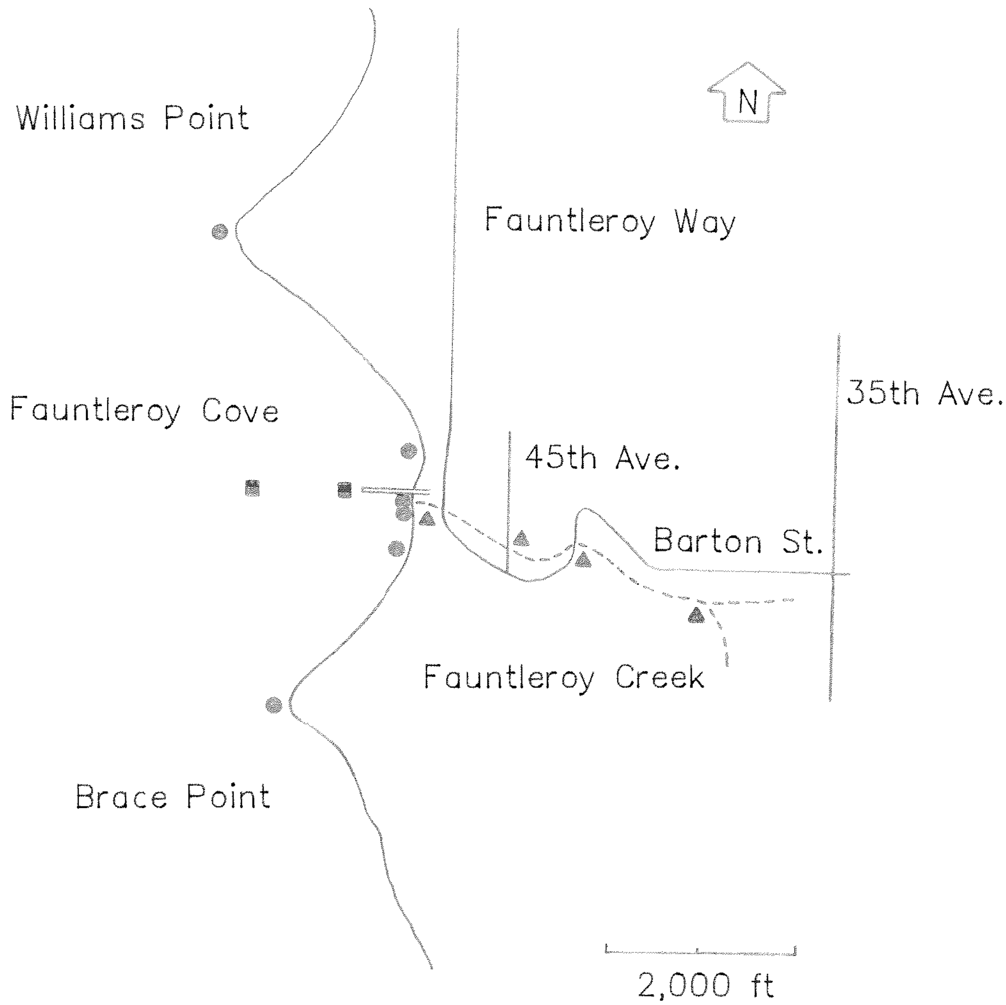

Figure 1. Map of Fauntleroy Creek and Cove showing location of creek (triangles), nearshore (circles), and offshore (squares) sampling sites.

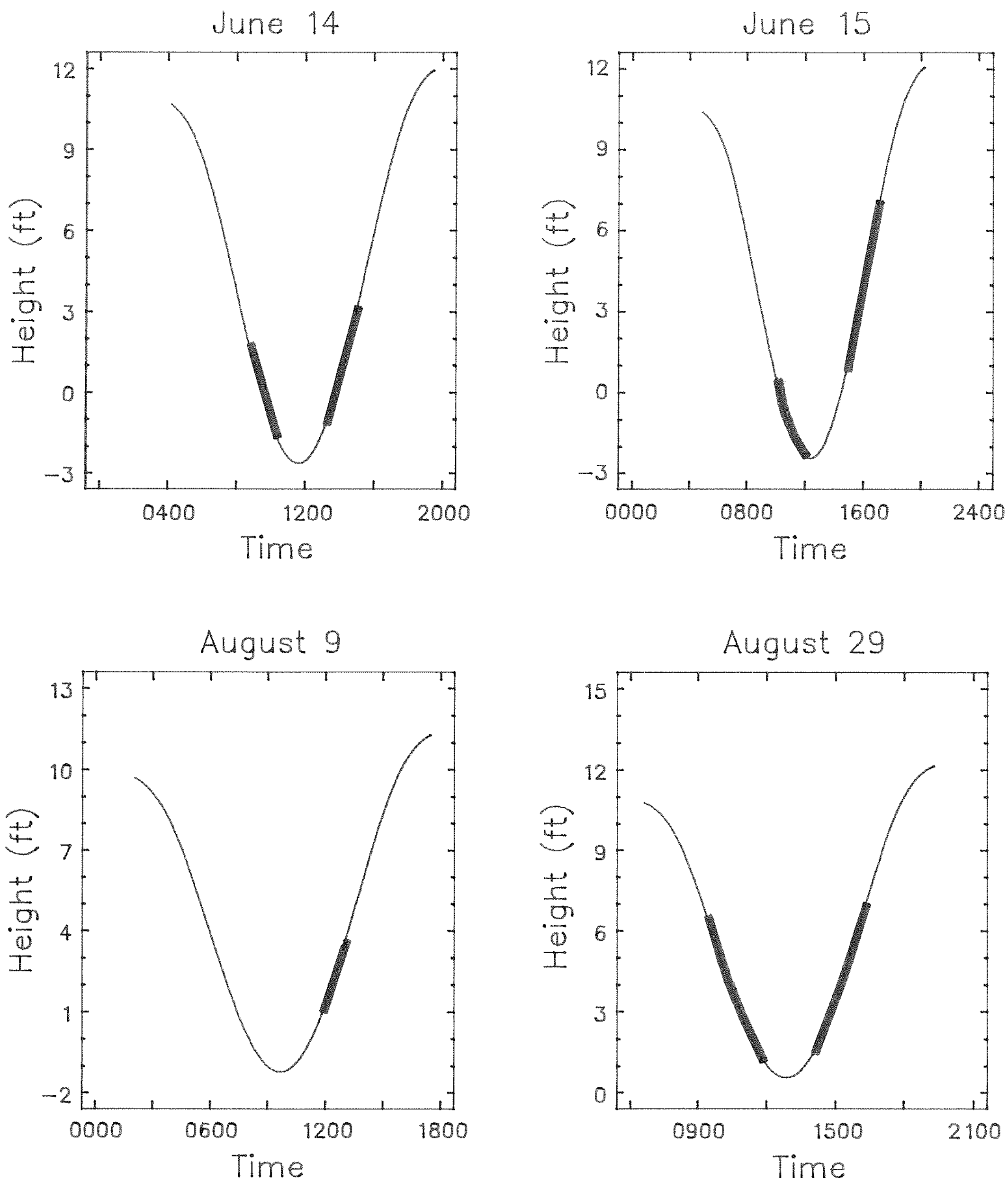

Figure 2. Tidal conditions during Fauntleroy field studies, summer 1988. Thickened portions of tide plots denote marine sampling intervals.

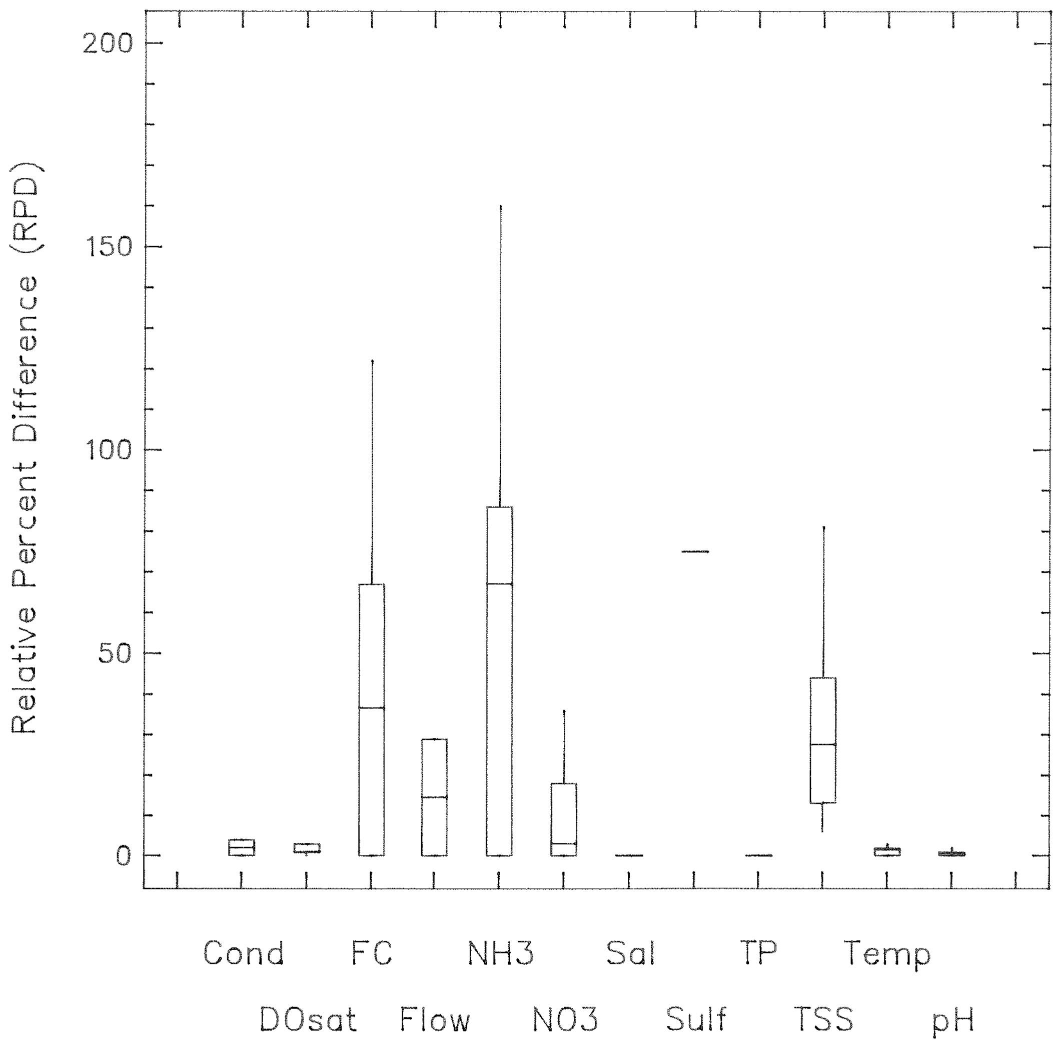

Figure 3. Comparison of replicate samples and measurements taken during surveys of Fauntleroy Creek and Cove in June and August 1988. Parameter codes are: Cond =conductivity; DOsat = dissolved oxygen (percent saturation); FC = fecal coliform; NH_3 = ammonia-nitrogen; NO3 = nitrate-plus-nitrite-nitrogen; Sal=salinity; Sulf = total sulfides; TP =total phosphorus; TSS = total suspended solids; Temp = temperature. Each box plot represents 6 sample replicates, except Cond (2), Flow (2), Sal(4), and Sulf (1).

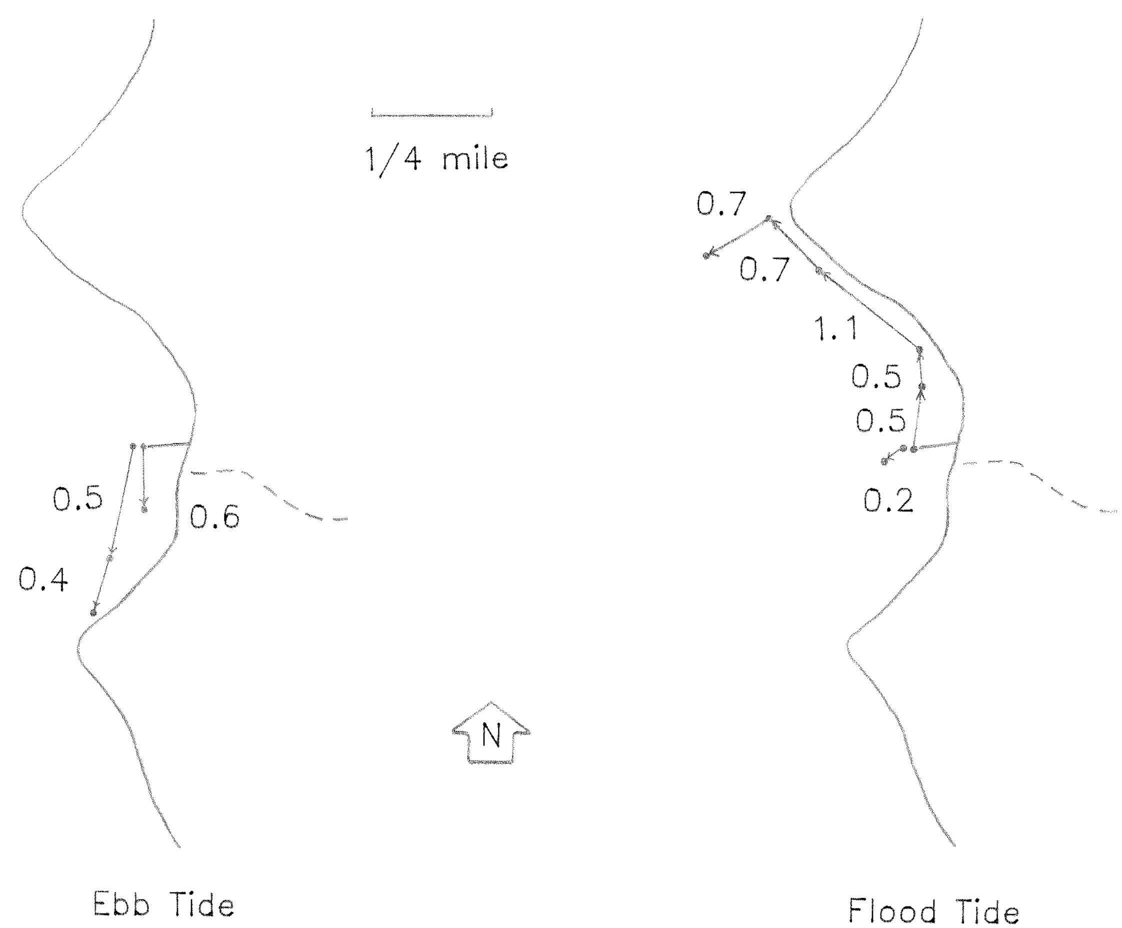

Figure 4. Offshore currents in Fauntleroy Cove on June 14, 1988. Drift drogues were launched near the end of the ferry dock. Tracking lines connect points of drogue position; numerals denote current velocity in units of feet per second; dashed line represents Fauntleroy Creek. Winds approached from the northwest.

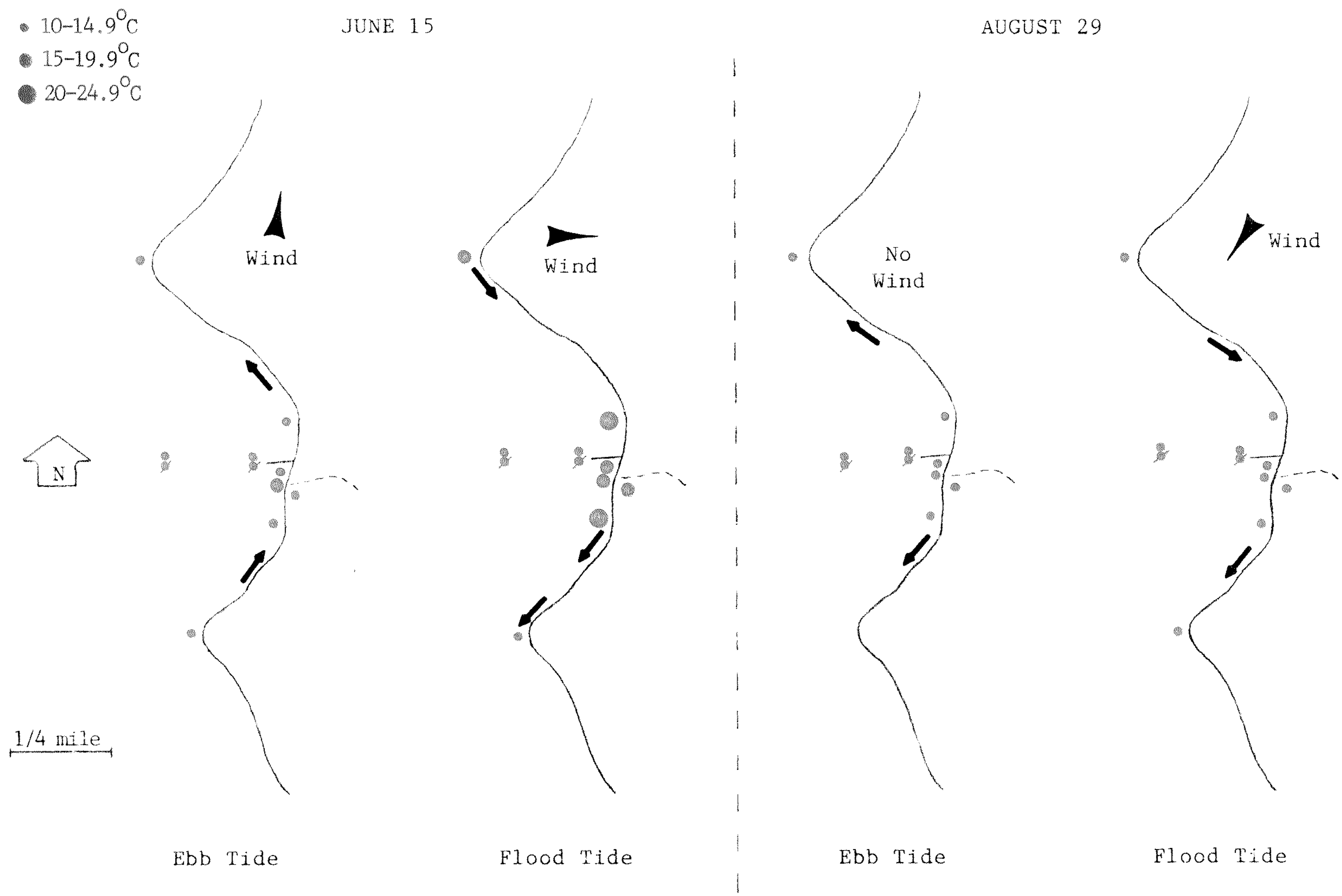

Figure 5a. Temperature range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

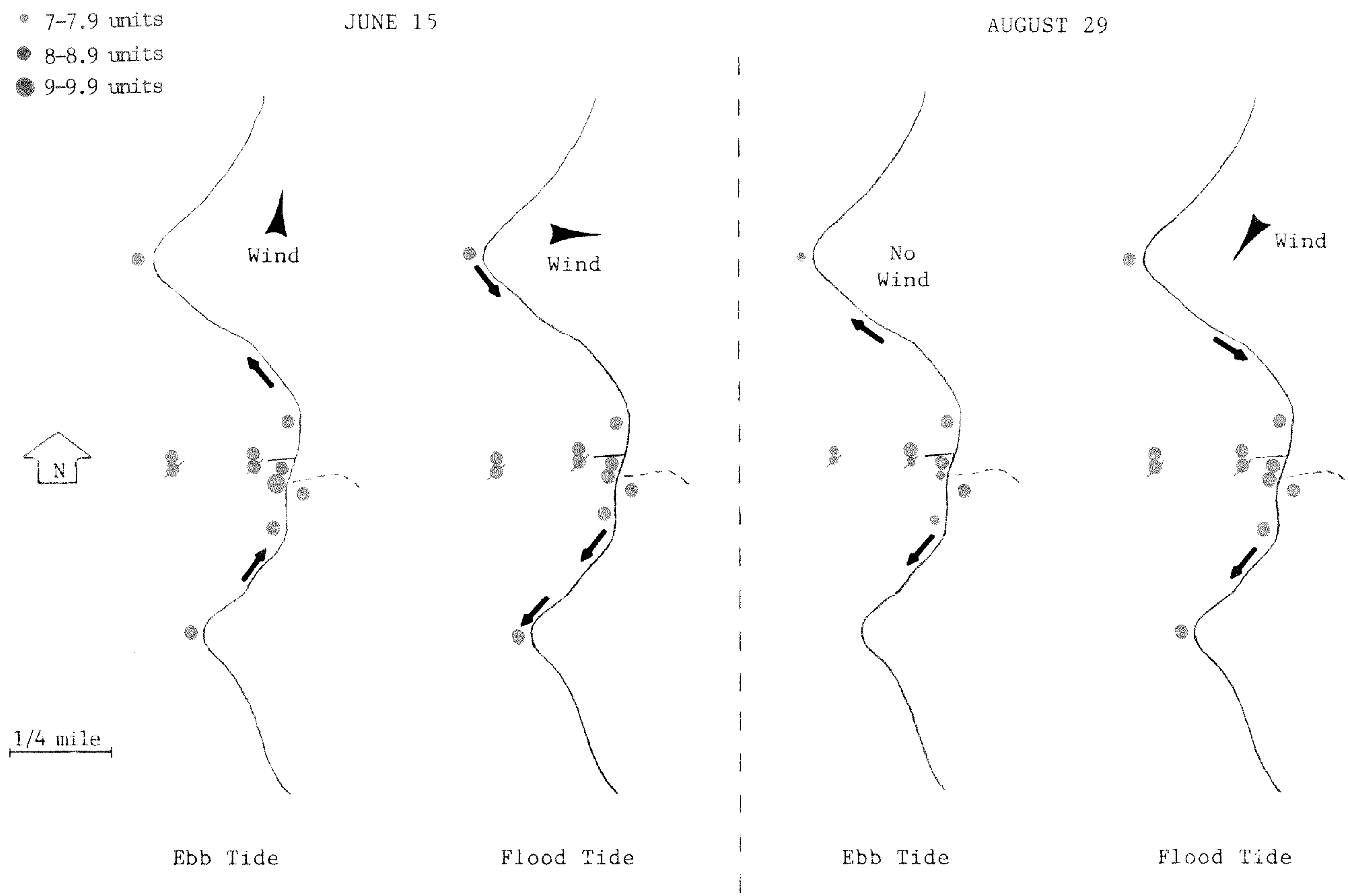

Figure 5b. pH range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

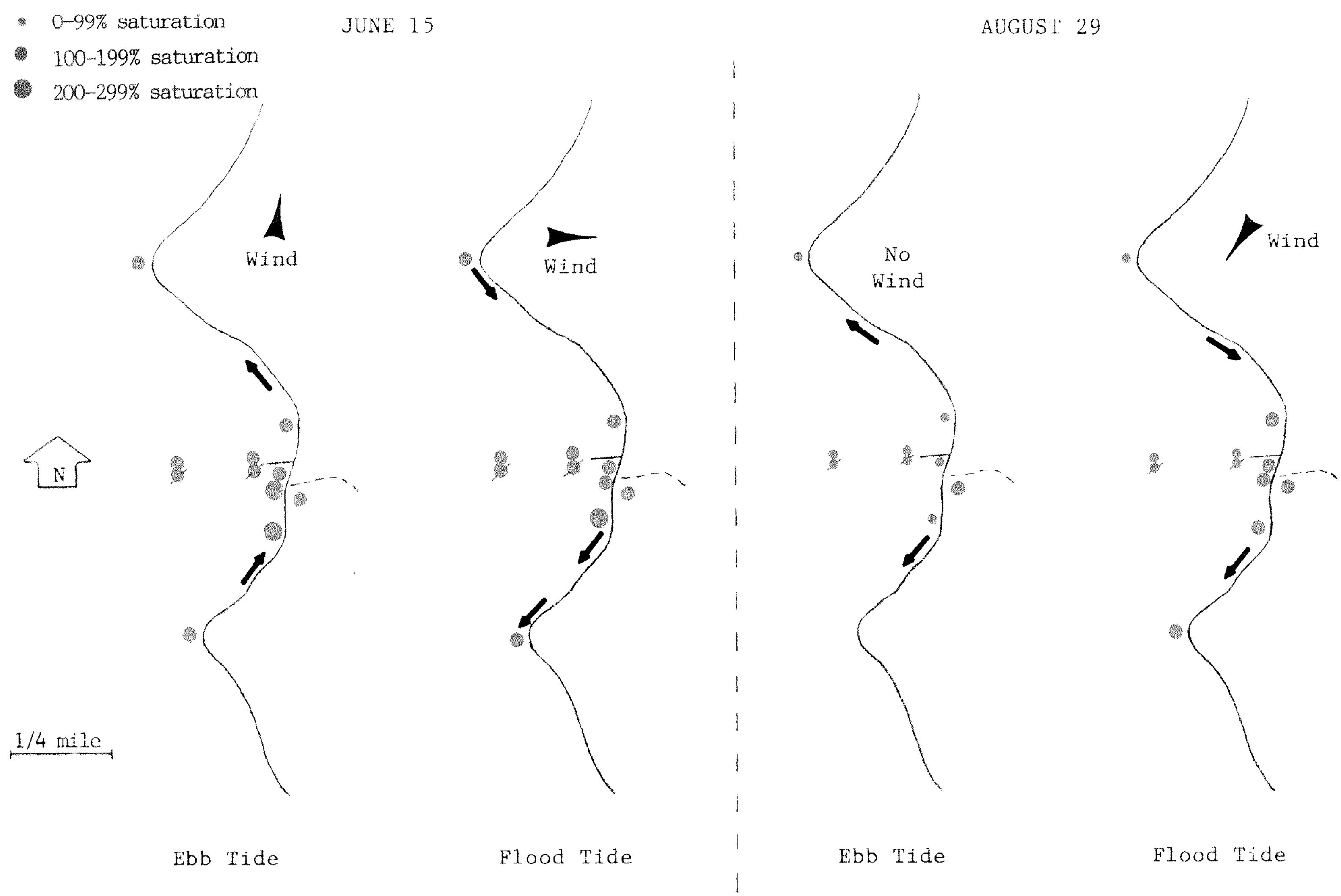

Figure 5c. Dissolved oxygen range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

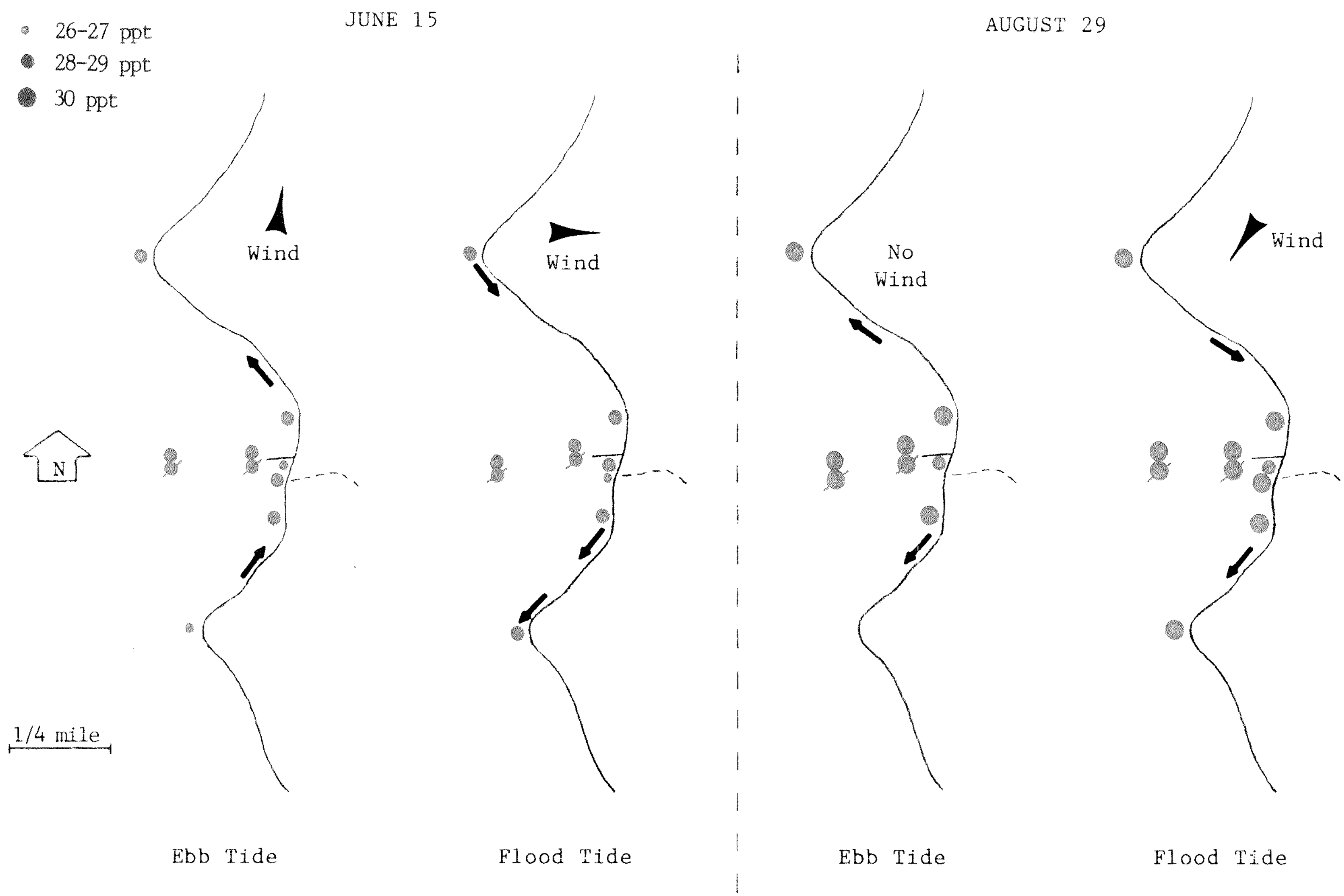

Figure 5d. Salinity range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

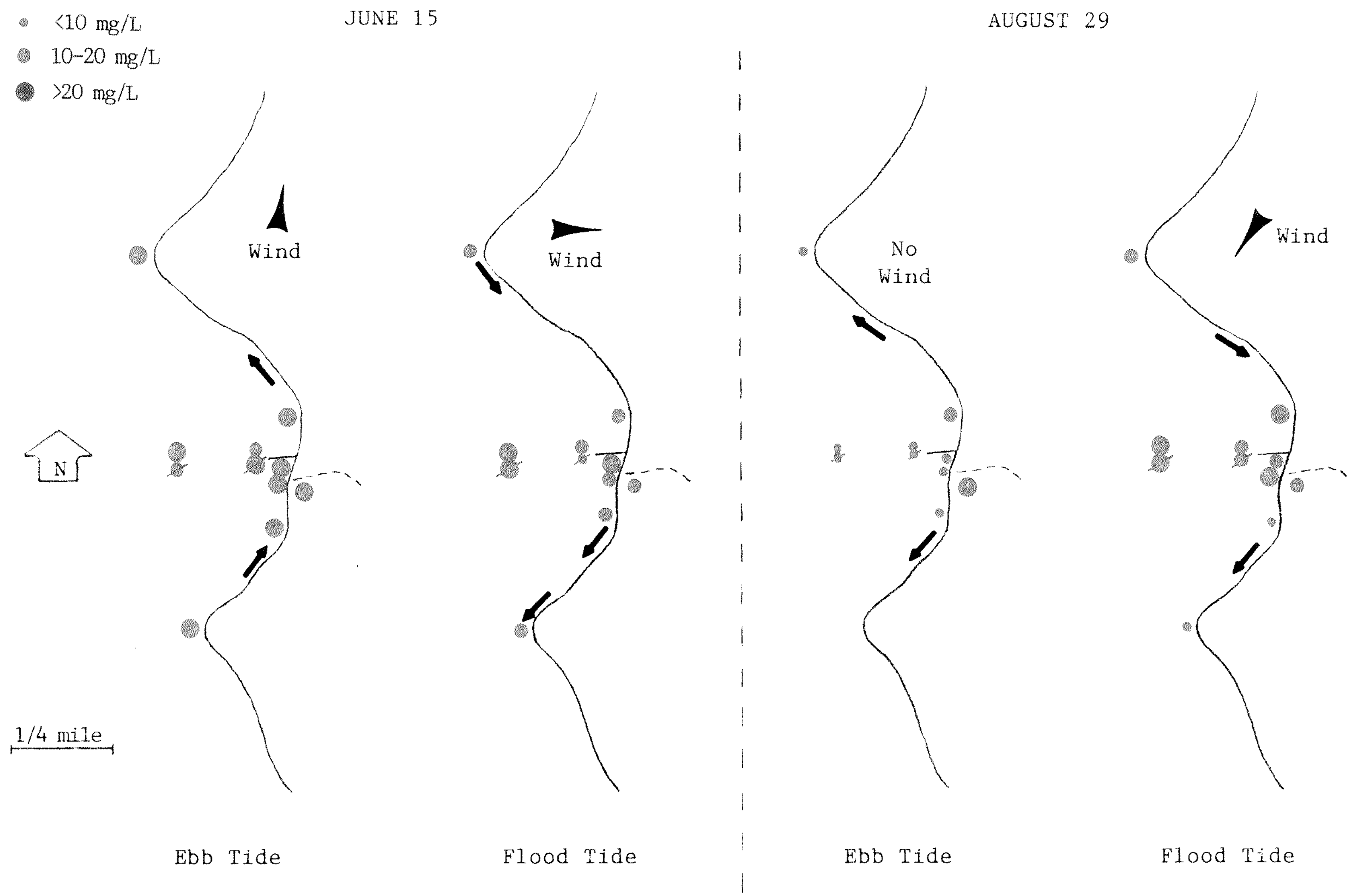

Figure 5e. Total suspended solids range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

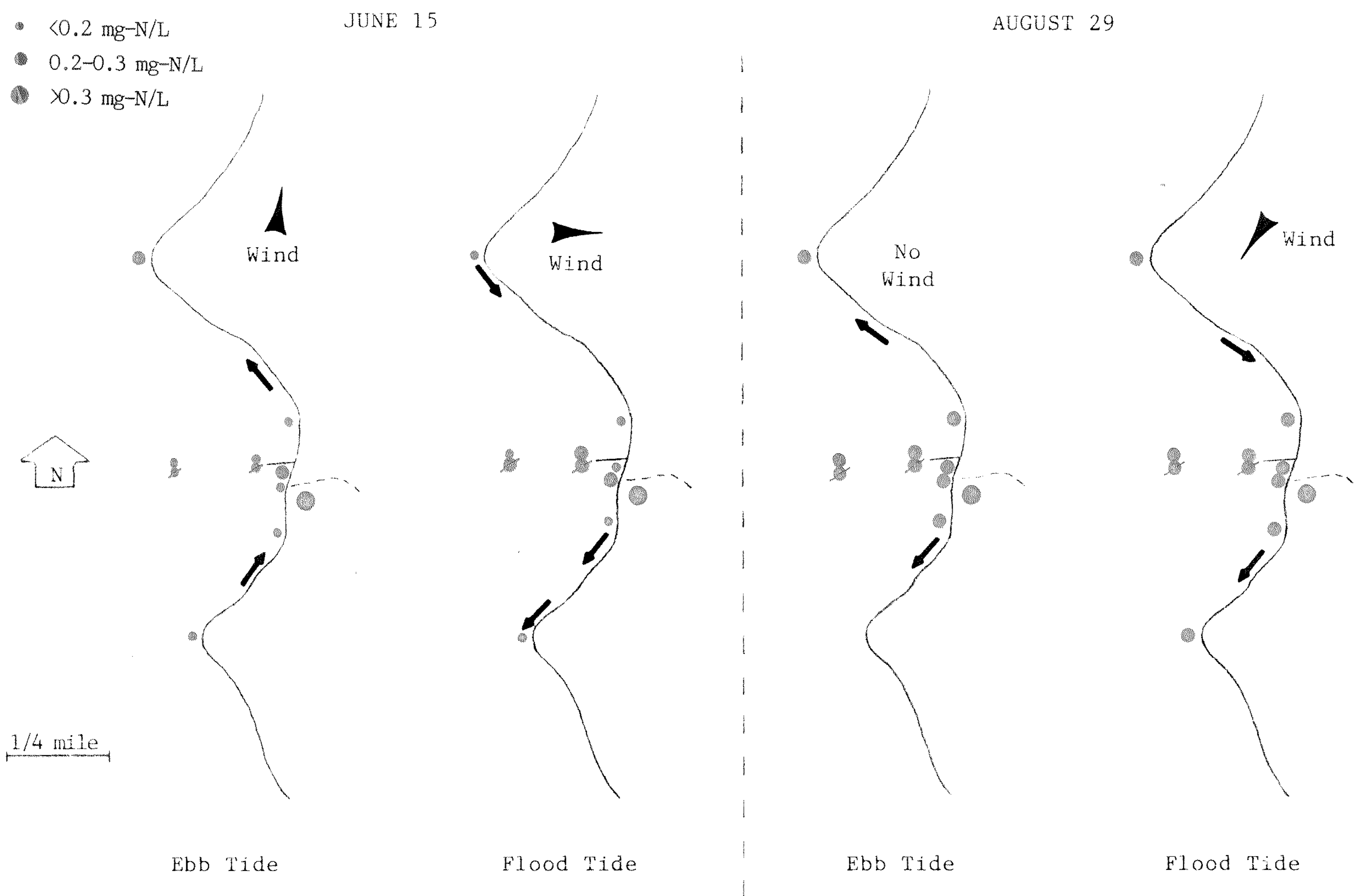

Figure 5f. Total inorganic nitrogen range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

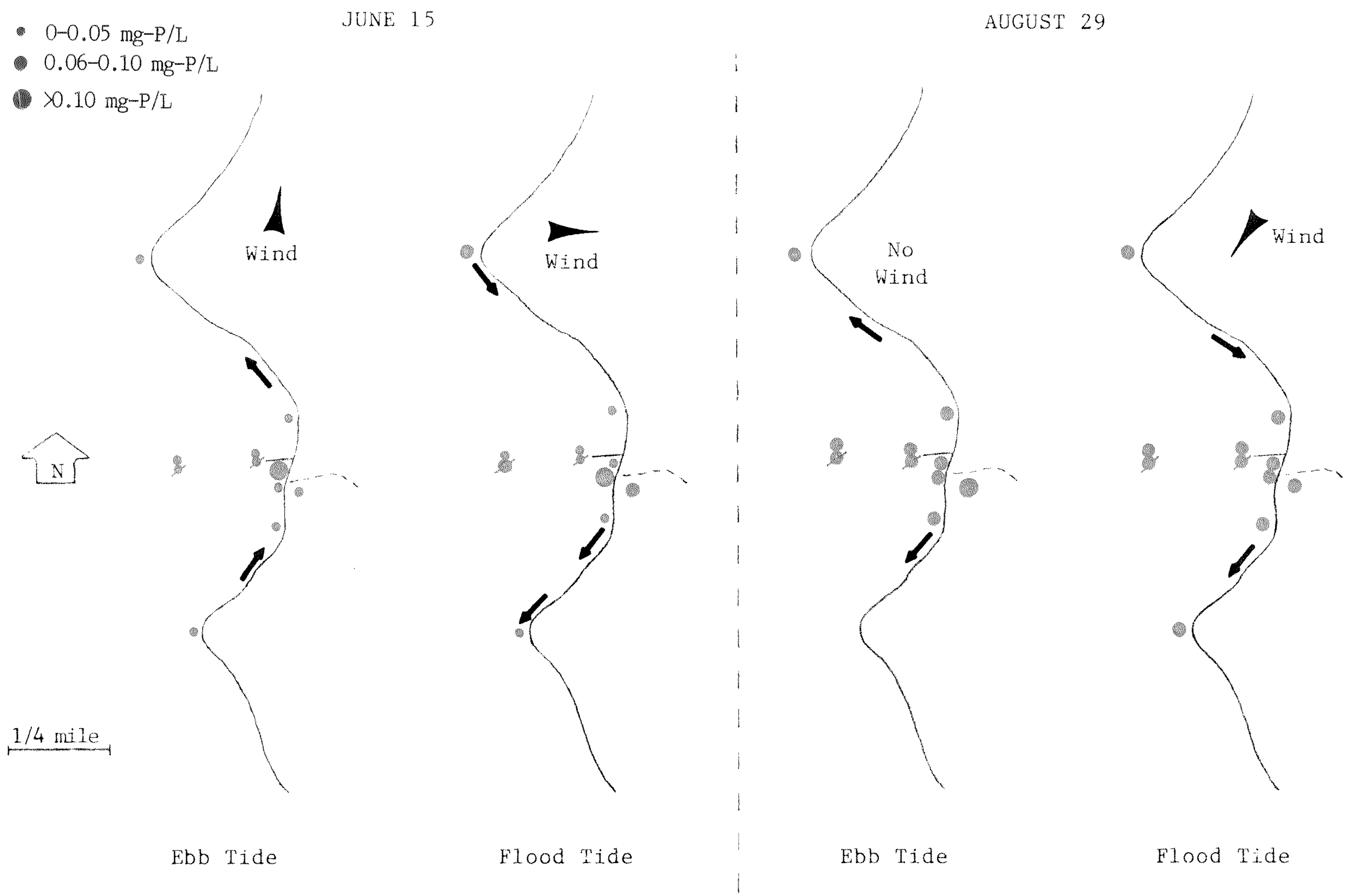

Figure 5g. Total phosphorus range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

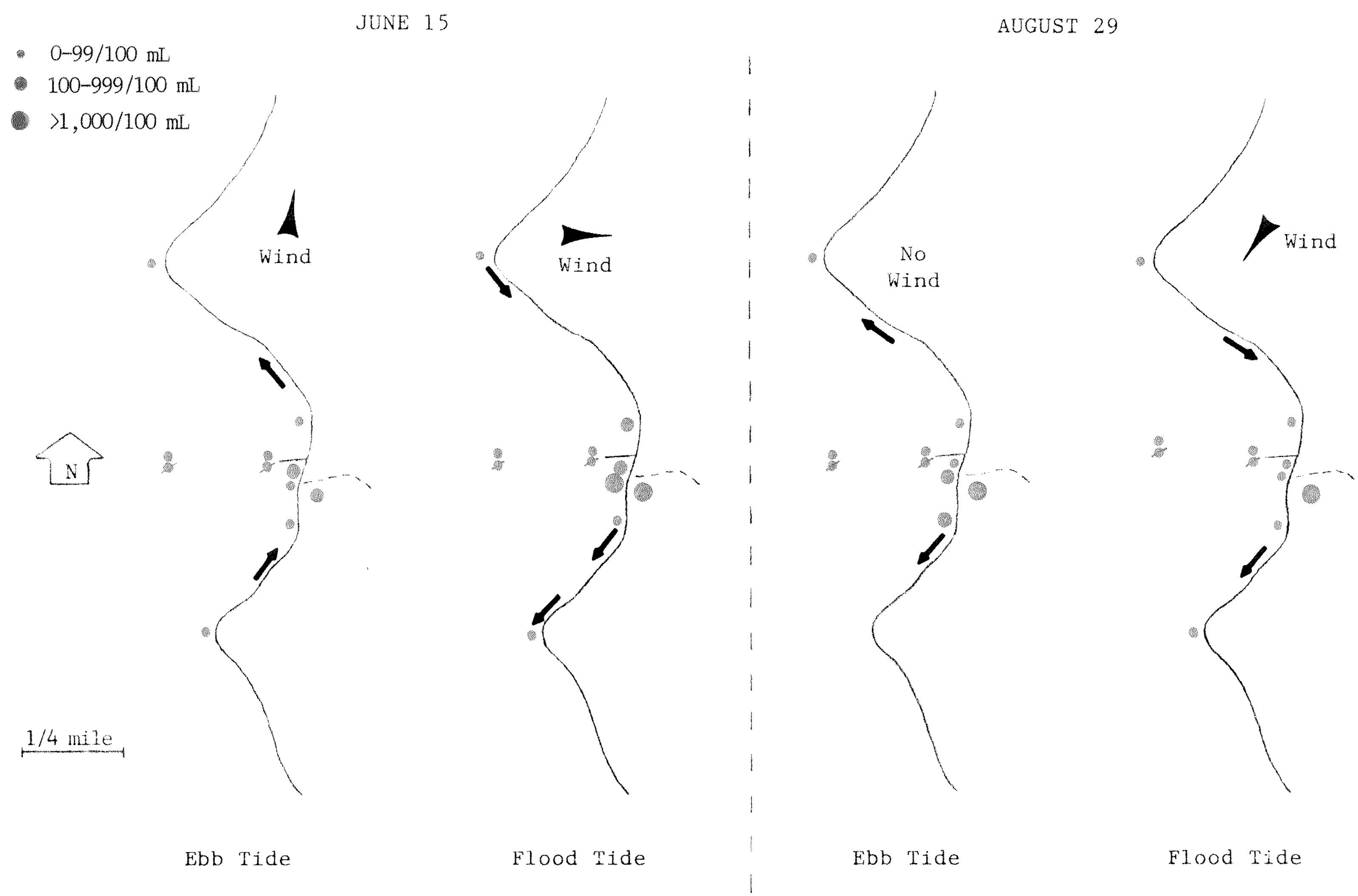

Figure 5h. Fecal coliform range in Fauntleroy Cove during summer 1988. Dashed line denotes Fauntleroy Creek. Symbol with line drawn through (ø) indicates sample from 30-foot depth. Arrows show direction of nearshore current movement (determined by dye studies during sampling).

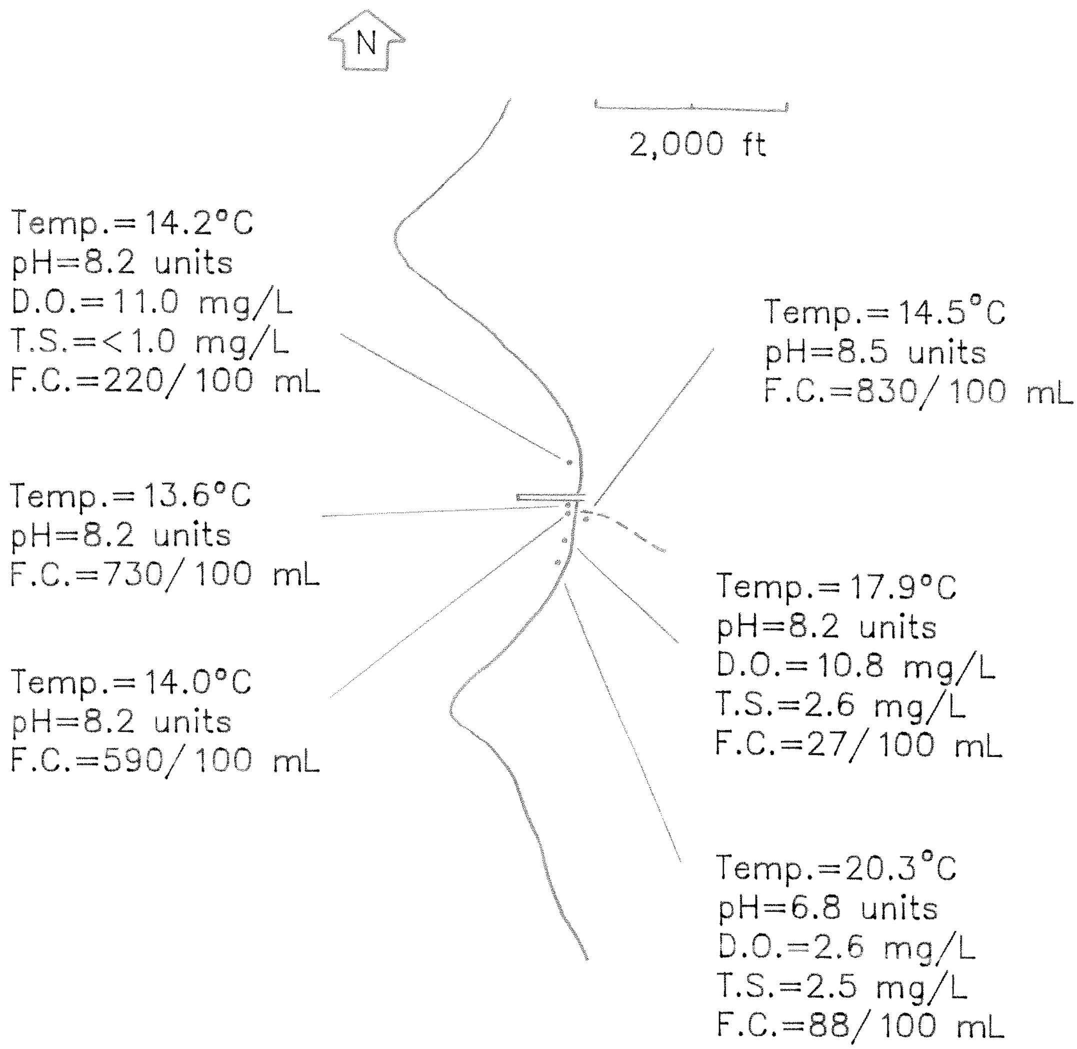

Figure 6. Nearshore water quality in Fauntleroy Cove during an afternoon flood tide on August 9, 1988 (D.O. = dissolved oxygen; T.S. = total sulfide; F.C. = fecal coliform).

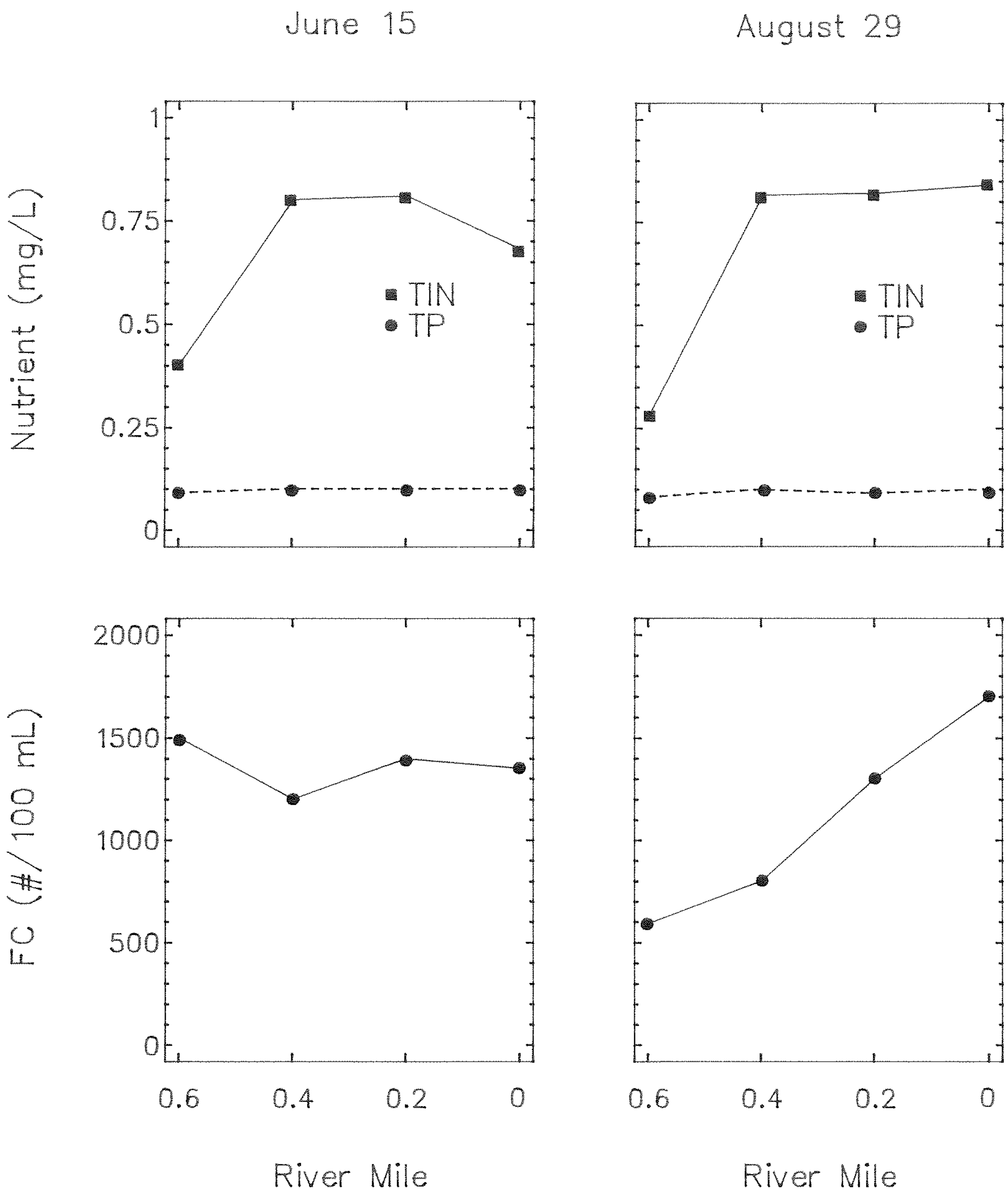

Figure 7. Total inorganic nitrogen (TIN), total phosphorus (TP), and fecal coliform (FC) concentrations in Fauntleroy Creek on June 15 and August 29, 1988.